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| <p>A literature search has been performed because of interest by the Troop Support Agency in the nutritive value of foods prepared and frozen in a central preparation facility and subsequently reheated in dining halls. Abstracts of 787 articles generated by a search of three computer systems, two data bases, and food journals were perused for content. Little data are available on large quantity production of precooked, frozen foods. Losses of vitamins and minerals are found resulting from pre-treatment, freezing and reheating. Since few people</p> |   |   |

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**20. Abstract (cont'd)**

are currently using this feeding system, there is a dearth of available literature and more work must be done. Both food processors and equipment manufacturers would benefit from more research on this subject. From the information available it does not appear that the nutrition of the consumer will be any more nutritionally altered by this feeding system than by any other system in use today.

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## PREFACE

A literature search has been performed because of interest by the U.S. Army Troop Support Agency, Fort Lee, Virginia, in the nutritive value of foods prepared and frozen in a central preparation facility and subsequently reheated in dining halls. Abstracts of 787 articles received from a search of three computer systems, two data bases, and additional food journals were perused for content. Little data has been published on large quantity production of precooked, frozen foods. Losses of vitamins and minerals resulted from pretreatment, freezing, and reheating. A modicum of information has been reported on changes in nutrient values of mixed foods. More data are available on nutrient losses in fruits and vegetables. Most investigators report minimal losses from the freezing process. Losses of the more labile vitamins are greater during storage above 0°F. The dearth of information available may be due to the comparatively recent implementation of cook/freeze systems on a large scale. Much more work needs to be carried out to determine the actual nutritional effects from use of the cook/freeze system.

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## **EFFECTS OF PROCESSING AND REHEATING ON NUTRIENT CONTENT OF PRECOOKED FROZEN FOODS**

### **INTRODUCTION**

The use of a convenience food system, in this instance — central preparation, has been evaluated at Fort Lee. The Troop Support Agency was interested in determining what effects, if any, prior cooking, freezing, and subsequent reheating would have on the nutrients of the prepared foods. The seriousness of the losses depends logically on the nutrients and their contribution to the total diet. A search of the literature has been performed to determine what work has been reported on this subject. Little data are available, particularly for large volume preparation. De Ritter et al. had reported on individual servings of frozen convenience dinners and pot pies in 1974;<sup>1</sup> and Fenton, who surveyed the literature in 1960, found reports on only 12 studies on nutritive losses during large-scale preparation of foods of animal origin for direct serving.<sup>2</sup> The present report covers the findings through 1978.

### **PROCEDURE**

On-Line searches were made in several computer systems and data bases. The computer systems — (1) DIALOG, the Lockheed Information System, (2) the Defense RDT&E On-Line System and (3) ORBIT, the System Development Corporation — were provided by the Technical Library at the Natick Laboratories. The Foreign Intelligence Officer at Natick searched (1) AGRICOLA, the Department of Agriculture data base and (2) CIRC, the DoD Scientific and Technical Intelligence System and data base. Abstracts of 787 articles were found and perused for content. Unclassified foreign documents on food technology of military significance revealed not one article on the nutritive value of prepared frozen meals. These searches covered reports from six free-world and six communist countries. Volumes 42 to 72 of the Journal of the American Dietetic Association from 1962 to 1978 and the Journal of the Institute of Food Technology from 1966 to 1977 yielded the majority of the articles.

### **RAW FOODS AND NUTRIENTS**

De Ritter states that the variations in the nutrient content of raw food may be due to genetic differences, climatic conditions, and maturity at harvest.<sup>3</sup> Losses of vitamins from the same vegetable can differ with different varieties, according to work done by Hopp and

<sup>1</sup>E. De Ritter, M. Osadca, J. Scheiner, and J. Keating. "Vitamins in Frozen Dinners and Pot Pies", J. American Dietetic Assoc., 64:391, 1974.

<sup>2</sup>F. Fenton. "Effects of Large Scale Preparation on Nutrients of Foods of Animal Origin", Chapter 10, in Part A, Nutritional Evaluation of Food Processing, Harris and Von Loesecke, 1960.

<sup>3</sup>E. De Ritter. "Stability Characteristics of Vitamins in Processed Foods", Food Technology, 30:1, 78, 1976.

Merrow.<sup>4</sup> Advocates of frozen food claim that the freezing of foods fresh from the vine provides a higher nutritional value than the so-called "fresh" item that may be a week in transit from the field to the table. In a lengthy report on the nutrient value of frozen vegetables as compared to fresh and canned vegetables, Sam Martin, the editor of Quick Frozen Foods, states that frozen vegetables are nutritionally superior to fresh vegetables for most nutrients. He refutes the prevalent consumer idea that since a frozen product is processed, it must inevitably be inferior to fresh, and cites tests on five vegetables (peas, corn, green beans, spinach, and fardhook lima beans) to prove his point.<sup>5</sup>

## **1. LOSSES IN PROCESSING**

Losses of nutrients during processing of fruits and vegetables result from peeling or trimming and from leaching during water blanching. Harris and Von Loesecke report that under adverse conditions the losses of vitamins during blanching can amount to 70%, but under favorable conditions can be as little as 5 to 10%.<sup>6</sup> Glew reports that the greatest loss of B vitamins is by leaching into water during the cooking of vegetables.<sup>7</sup> However, since freezing has a softening effect on the texture of vegetables, the cooking time can be reduced, which will minimize leaching losses.

## **MINERAL LOSSES**

The loss of minerals by leaching into the water is not a matter of nutritional concern. In fact, foods can absorb minerals from the cooking liquid, which can be a matter of concern to those planning mineral-restricted diets.

## **VITAMIN LOSSES — VITAMIN A AND CAROTENE**

Harris and Von Loesecke report a study done by Volz, et al. in 1949 on the nutritive value of peas, spinach, corn, and green beans.<sup>8</sup> They found that although moisture losses

<sup>4</sup>R. J. Hopp and S. B. Merrow. "Varietal Differences and Storage Changes in the Ascorbic Acid Content of Six Varieties of Winter Squashes", J. Agricultural Food Chemistry, 11:143, 1963.

<sup>5</sup>S. Martin. "Nutrient Values of Frozen Vegetables as Compared to Fresh and Canned", Quick Frozen Foods, 40:4, 34, 1977.

<sup>6</sup>R. Harris and H. Von Loesecke. (Ed.) "Nutritional Evaluation of Food Processing", Wiley & Sons, Inc., 1960.

<sup>7</sup>G. Glew. "Cook/Freeze Catering — An Introduction to Its Technology", Faber and Faber, London, England, 1973.

<sup>8</sup>See reference 6.

of 12 to 25% occurred during 12 months storage at 0°F, the degree of desiccation before or during storage at 0°F did not influence the appearance, flavor, or the vitamin A content of the vegetables after cooking. De Ritter states that caroteneoids in vegetables and fruits are usually stable during blanching, retorting, and freezing, and further adds that in frozen and heat-sterilized foods, carotenoids show good storage stability in most cases.<sup>9</sup>

## VITAMIN C

Vitamin C is one of the most readily destroyed of the vitamins. Because of this lability, its retention is often used as an index of the effect of processing and storage. Bender reports that if the vitamin C is well retained, then it is unlikely that there has been a serious loss of other nutrients.<sup>10</sup> Eheart, in studies with broccoli, reports that approximately 35% of the original ascorbic acid was lost in blanching, 7% in freezing and storage for one year, and a further 10% in cooking the frozen samples.<sup>11</sup> Harris and Von Loesecke report that under adverse conditions, the losses of vitamins during blanching can amount to 70%, but under favorable conditions can be as little as 5 to 10%.<sup>12</sup> Glew in England reports losses in vitamin C from 26% to 72% between cooking and subsequent serving in school kitchens and in a hospital feeding situation.<sup>13</sup> A serving of frozen peas that had 20.5 mg of ascorbic acid when removed from the freezer had only 1.1 mg of ascorbic acid when it reached the patient. These data substantiate claims that the cooking process and subsequent handling are very important for nutrient retention. Sweeney, et al. found that though the ascorbic acid content of uncooked frozen broccoli was somewhat lower than that of fresh broccoli, the retention of this vitamin in the ready-to-serve product was not significantly different in either form.<sup>14</sup> The Staff of the Catering Research Unit at the University of Leeds, after studying vitamin retention in bulk frozen and conventionally prepared foods, claimed a significantly higher percentage of ascorbic acid with their cook/freeze system than in their conventional system.<sup>15</sup>

<sup>9</sup>See reference 3.

<sup>10</sup>A. E. Bender. "Nutritional Effects of Food Processing", J. Food Technology, 1, 261, 1966.

<sup>11</sup>Mary S. Eheart. "Effect of Microwave vs. Water-Blanching on Nutrients in Broccoli", J. Amer. Dietetic Assoc., 50:207, 1967.

<sup>12</sup>See reference 6.

<sup>13</sup>See reference 7.

<sup>14</sup>J. P. Sweeney, G. L. Gilpin, M. E. Martin, and E. H. Dawson. "Palatability and Nutritive Value of Frozen Broccoli", J. Amer. Dietetic Assoc., 36:122, 1960.

<sup>15</sup>Staff, Catering Research Unit, University of Leeds, U.K. "An Experiment in Hospital Catering Using the Cook/Freeze System", 1970.



From the literature reviewed, the greatest losses in ascorbic acid appear to come from pre-preparation involving peeling, trimming, and blanching rather than freezer storage.

## B VITAMINS

Glew reports the greatest loss of B vitamins is by leaching into water during the cooking of vegetables.<sup>16</sup> The commercial operations of washing, blanching, and cooling necessary in the preparation for freezing are responsible for appreciable losses of vitamins, not freezer storage.

Losses in thiamin are greater than losses in riboflavin and niacin according to Morgan, et al.<sup>17</sup> Few reports were found on the effect of cooking and storage on the nutritive content of poultry.

## 2. EFFECTS OF STORAGE ON VITAMINS

Effects of storage time and temperature have been investigated by a number of food scientists. Kramer claims that a 5°F freezer temperature not only maintains the sensory quality of vegetables like asparagus, green and lima beans, and peas, but that 90% of the ascorbic acid will be maintained for 12 months when products are stored at this temperature.<sup>18</sup> There was only a 20% difference in the ascorbic acid content between freshly cooked broccoli and beans and the blanched frozen product stored six months at 0°F. These findings were reported by Noble and Gordon in 1964.<sup>19</sup>

Kramer reports that vitamin content may deteriorate more rapidly than sensory quality in some cases, yet the reverse could be true in other cases. He cites orange juice concentrate as an example of a product which retained its quality for over two years at 0°F and will lose less than 10% of the vitamin even at temperatures as high as 40°F.<sup>20</sup> Lachance, et al. reports that vitamin losses in frozen foods are doubled or tripled with each five-degree increase in storage temperature above 0°F.<sup>21</sup>

<sup>16</sup>See reference 7.

<sup>17</sup>A. F. Morgan, L. E. Kidder, M. Hunner, B. K. Sharokin, and R. M. Chesbro. "Thiamine, Riboflavin, and Niacin Content of Chicken Tissues as Affected by Cooking and Frozen Storage", *Food Research*, 14:439, 1949.

<sup>18</sup>Amihud Kramer. "Storage Retention of Nutrients", *Food Technology*, 28:1, 50, 1974.

<sup>19</sup>Isabel Noble and Joan Gordon. "Effect of Blanching Method on Ascorbic Acid and Color of Frozen Vegetables," *J. Amer. Dietetic Assoc.*, 44:120, 1964.

<sup>20</sup>See reference 18.

<sup>21</sup>Paul A. Lachance, A. S. Ranadine, and J. Matas. "Effects of Reheating Convenience Foods", *Food Technology*, 27:1, 36, 1973.

J. F. Feaster in a publication edited by Harris and Von Loesche<sup>22</sup> (see Table 1) cites work performed by L. G. Davis that shows a high percentage of ascorbic acid retained in frozen vegetables stored four months at 0°F. For this same time, 80 to 90% of the prestorage amount of the vitamin was retained in broccoli, green beans, and spinach. Wax beans and lima beans retained 95 and 92%, respectively, and peas and asparagus 100%. The majority of these same vegetables retained 100% when stored at -20°F.

The B vitamins appear to be retained to a high degree during the storage of frozen vegetables. According to Feaster, riboflavin, niacin, thiamin, and other B vitamins should be retained to a high degree under storage conditions acceptable for the retention of ascorbic acid. Harris holds that B vitamins should be retained to a high degree during freezer storage.<sup>23</sup> However, available data showing the influence of storage under commercial conditions on survival of these nutrients are extremely limited. He states that more data establishing B-vitamin stability should be developed. Burger, et al. in 1956 reported that the capability of the freezing process in retaining most nutrients is well recognized.<sup>24</sup> Van Arsdel, et al. reported that of all foods studied, none lost significant amounts of B-vitamins during the freezing process.<sup>25</sup> The commercial operations of washing, blanching, and cooking, necessary for the preparation for freezing, are responsible for appreciable losses of vitamins, rather than freezer storage. In analyzing 12 frozen and 24 canned fruits and fruit juices Schroeder found that the loss of B<sub>6</sub> was 15.4% from freezing and 37.67% from canning.<sup>26</sup> Adam reports that in general the retention of vitamins in quick frozen fruits and vegetables is higher than in canned foods.<sup>27</sup> This is particularly so for thiamin, since this vitamin is destroyed to an appreciable percent in canning.

<sup>22</sup> See reference 6.

<sup>23</sup> See reference 6.

<sup>24</sup> M. Burger, N. W. Hern, L. J. Teply, P. A. Derse, and C. H. Kruger. "Vitamin, mineral and proximate composition of frozen fruits, juices and vegetables," *J. Agric. Food Chem.*, 4,418, 1956.

<sup>25</sup> W. B. Van Arsdel, M. J. Copley, and R. L. Olson. "Quality and Stability in Frozen Foods", Wiley - Interscience, 1969.

<sup>26</sup> Henry A. Schroeder. "Losses of Vitamins and Trace Minerals Resulting from Processing and Preservation of Foods", *American J. Chemical*, 1971.

<sup>27</sup> W. B. Adam. "Progress and Problems of Quick-Freezing of Fruit and Vegetables" in "Recent Advances in Food Science" edited by J. Hawthorn, J. Leitch, and J. Muil, Vol. 2, p. 185, 1962.

TABLE 1.  
FOODS OF PLANT ORIGIN

| Vegetable   | Prestorage<br>Ascorbic<br>Acid<br>mg/100 g | Storage<br>Time<br>Months | % Retention at |      |        |
|-------------|--|---------------------------|----------------|------|--------|
|             |  |                           | 10° F          | 0° F | -20° F |
| Asparagus   | 40   | 4                         | 50             | 100  | 100    |
|             |  | 8                         | 10             | 90   | 100    |
|             |  | 12                        | 10             | 90   | 100    |
| Broccoli    | 78   | 4                         | 50             | 80   | 95     |
|             |  | 8                         | 20             | 80   | 90     |
|             |  | 12                        | 15             | 73   | 90     |
| Green Beans | 14   | 4                         | 45             | 85   | 100    |
|             |  | 8                         | 30             | 85   | 100    |
|             |  | 12                        | 5              | 70   | 100    |
| Wax Beans   | 22   | 4                         | 35             | 95   | 100    |
|             |  | 8                         | 25             | 90   | 100    |
|             |  | 12                        | 15             | 75   | 100    |
| Lima Beans  | 21   | 4                         | 80             | 92   | 96     |
|             |  | 8                         | 72             | 95   | 98     |
|             |  | 12                        | 47             | 74   | 86     |
| Cauliflower | 78   | 4                         | 70             | 95   | 100    |
|             |  | 8                         | 30             | 55   | 80     |
|             |  | 12                        | 20             | 50   | 80     |
| Peas        | 17   | 4                         | 75             | 100  | 100    |
|             |  | 8                         | 58             | 95   | 100    |
|             |  | 12                        | 21             | 89   | 98     |
| Spinach     | 31   | 4                         | 45             | 85   | 100    |
|             |  | 8                         | 15             | 50   | 85     |
|             |  | 12                        | 10             | 45   | 90     |

\*Adapted from Davis (1956).

Note: See Reference 6.

Since meat is one of the best dietary sources of B vitamins, more studies are reported in retention and destruction of B vitamins in animal products. Livingston, et al. reports that the retention of these nutrients in freezing and subsequent storage of meat products is high, provided storage temperatures are low and adequate protective packaging is used.<sup>28</sup> Engler and Bowers report no consistent trend of retention in freezer storage time as related to thiamin, riboflavin, niacin and pantothenic acid in meat. Riboflavin is not affected by heat, so that heating is not of great concern as long as the foods are properly packaged to prevent damage from light. They further reported that niacin, B<sub>6</sub>, and pantothenic acid are not lost during the freezer storage.<sup>29</sup> It is interesting to note that Hardinge and Crooks in a table on the lesser known vitamins in food grouped "Fresh or Frozen" vegetables contributing the same amounts of B<sub>6</sub>, pantothenic acid, biotin, folic acid, choline and inositol.<sup>30</sup> Fennema in 1975 found losses of B vitamins during the entire process, but mostly during the freezer storage and thawing of the frozen animal tissue.<sup>31</sup>

Hulse, reporting on precooked chicken and turkey meals, claims that the precooked products deteriorated faster than their frozen raw equivalent, and that, if these products are to have a good shelf life, they should be stored well below 0°F. At 0°F the meat will develop stale flavor, and loss of juiciness will occur after four to six months storage.<sup>32</sup>

Losses in thiamin are greater than losses in riboflavin and niacin, according to Morgan, et al.<sup>33</sup> In a study of chicken, analyses were made in the raw meat, on the meat immediately after standardized cooking, and on the product after holding in freezer storage from three to twelve months. In nearly all tissues, loss of niacin was negligible for freezer storage up to eight months, but in some cases the losses were 25 to 50% after 12 months storage. Riboflavin was well retained — in most cases up to eight months. In the cooked meat, 20 to 40% of the thiamin disappeared and usually 10 to 20% of the riboflavin and niacin disappeared.

<sup>28</sup>G. E. Livingston, C. Ang, and C. M. Chang. "Effects of Food Service Handling," *Food Technology*, 27:1, 36, 1973.

<sup>29</sup>Pamela P. Engler and James A. Bowers. "B Vitamin Retention in Meat During Storage and Preparation", *J. Amer. Dietetic Assoc.*, 69:3, 253, 1976.

<sup>30</sup>M. G. Hardinge and Hulda Crooks. "Lesser Known Vitamins in Foods," *J. Am. Dietetic Assoc.*, 38:240, 1961.

<sup>31</sup>O. Fennema. "Effects of Freeze Preservation on Nutrients", *Nutritional Evaluation of Food Processing*, 2nd Edition, p. 214, edited by R. H. Harris and E. Karmas, Avi Publishing Co., Westport, Conn., 1975.

<sup>32</sup>J. H. Hulse. "Precooked Frozen Foods," In *Recent Advances in Food Science*, edited by J. Hawthorn, J. Leitch, and J. Muil, Vol. 2, p 199, 1962.

<sup>33</sup>See reference 17.

### 3. EFFECTS OF REHEATING

Kahn and Livingston say that the trend toward the convenience food service system with its reliance on central preparation and freezing may indeed offer some incidental nutritional benefits provided that the reheating of foods is carried out by rapid methods.<sup>34</sup> Concerning the nutritional implications of different methods of reheating in mass feeding operations, Ang and Livingston found that only limited information has been published.<sup>35</sup> Kahn and Livingston,<sup>36</sup> Glew,<sup>37</sup> De Ritter,<sup>38</sup> Engler and Bowers,<sup>39</sup> Morgan,<sup>40</sup> and others have studied various methods of preparing frozen foods and their nutrient losses.

When rapid heating methods such as microwave or infrared ovens are used, the retention of heat-labile nutrients in frozen, ready-to-heat food may be better than in foods prepared conventionally and held hot for a period of time before serving. This improved retention was demonstrated by Kahn and Livingston who compared precooked frozen entrees reheated by using microwave, infrared and hot water immersion techniques with freshly prepared products held in a bain-marie for 1, 2, and 3 hours.<sup>41-42</sup> Thiamin losses in the latter cases were 22, 26, and 33%, respectively, as opposed to a loss of 6.5% by reheating in microwave, 9.6% for infrared reheating, and 14% for hot water immersion reheating. The thiamin retention in three of four frozen entrees reheated by any of the rapid methods exceeded by at least 10% the retention in the fresh entrees held for one hours. In 1970 Glew claimed a significantly higher percentage of ascorbic acid with the British cook/freeze system than in their conventional system according to Livingston's data.<sup>44</sup>

<sup>34</sup> L. N. Kahn and G. E. Livingston. "Effect of Heating Methods on Thiamine Retention in Fresh or Frozen Prepared Foods", *J. Food Science*, 35:349, 1970.

<sup>35</sup> C. W. Ang and G. E. Livingston. "Effects of Various Reheating Methods on Nutrient Losses in Heated Ready-to-Heat Frozen Foods", unpublished data, 1977.

<sup>36</sup> See reference 34.

<sup>37</sup> See reference 7.

<sup>38</sup> See reference 3.

<sup>39</sup> See reference 29.

<sup>40</sup> See reference 17.

<sup>41</sup> C. A. Ang, C. M. Chang, A. E. Frey, and G. E. Livingston. "Effects of Heating Methods on Vitamin Retention in Six Fresh or Frozen Prepared Products", *J. of Food Science*, 40:997, 1975.

<sup>42</sup> See reference 34.

<sup>43</sup> See reference 7.

<sup>44</sup> See reference 35.

De Ritter found good retention of B<sub>12</sub> in a number of frozen convenience dinners (fresh fried chicken, turkey and beef): 79 to 100% of the vitamin was retained after reheating.<sup>45</sup>

Engler and Bowers found that meats held in the frozen state and then reheated retained significantly more thiamin and riboflavin but lost more B<sub>6</sub> than freshly cooked muscle. They report that when meat is heated by moist methods, more vitamins are transferred to the cooking drip than when dry heating methods are used.<sup>46</sup> With respect to destruction of the B vitamins, there is little difference between the methods of heating meat.

The losses of nutrients due to reheating precooked frozen foods depends on many factors. Ang and Livingston in their summary of the effects of reheating report that nutrient losses are dependent on several factors: (1) the type of nutrients — for example the retention of ascorbic acid can be very different from that of riboflavin or thiamin because each nutrient has its own stability characteristics; (2) the type, quantity, and configuration of the food — Is it packaged in bulk or individual portions? How much does packaging affect the heating, exposure to light, etc? (3) the container — "boil-in-bag" pouch is different than steamtable packaging; (4) the heating time and temperature of different ovens or steamers; (5) the handling of foods both during and after reheating; (6) the heating speed of the equipment. Rapid heating preserves more of the heat-labile nutrients. Ascorbic acid and thiamin were found unstable to heat, whereas riboflavin and carotene were more stable. Livingston concluded that much more work needs to be done by food scientists on nutrient retention in frozen foods. More work would benefit the ready-to-heat frozen food industry and the manufacturers of heating equipment in their efforts to devise procedures that will achieve maximum retention of nutrients in the foods offered for consumption.<sup>47</sup>

As reported by Lachance, et al. our knowledge of the loss of nutritive value in foods during processing storage and reheating is poor. Such losses should be viewed in relation to the importance they will have to the consumer.<sup>48</sup> Bender reports that half of the average vitamin C intake in Great Britain comes from potatoes, and losses in processing could be serious to individuals subsisting on a marginal intake of the vitamin.<sup>49</sup> To an elderly person living on a strictly limited number of foods, losses in one of the few may become important. On the other hand he notes the average adult is consuming possibly a hundred different foods, and it may be of little importance if any one of these suffer nutrient damage — unless that food happens to be a major source of a nutrient.

<sup>45</sup> See reference 3.

<sup>46</sup> See reference 29.

<sup>47</sup> See reference 35.

<sup>48</sup> See reference 21.

<sup>49</sup> See reference 10.

Until more feeding systems go to centralized production of foods, it is unlikely that more research in this area will be performed by the scientific community. However, from the information available it would appear that the consumer will be as well nourished from a precooked frozen food system as from other systems, fresh or canned, in use today.

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